MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

EOP4066 – OPTICAL COMMUNICATION SYSTEMS

(All sections/Groups)

15 OCTOBER 2016
2:30 p.m. – 4:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Answer **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (25 marks)

(a) The numerical aperture (NA) is a useful measure of the light-collecting ability of an optical fiber.

(i) With the help of a suitable equation, define NA in terms of the relative refractive index difference. [2 marks]

(ii) Will having a larger fiber core diameter have an effect on the fiber's NA? Justify your answer. [3 marks]

(iii) Which type of fiber has a larger NA? [2 marks]

(iv) A typical relative refractive index for an optical fiber is 1%. Calculate the critical angle at the core-cladding interface. [3 marks]

(b) Fibers can be classified according to its refractive index profile.

(i) With the help of a suitable equation, define refractive index. [2 marks]

(ii) Name two types of fibers which can be classified according to its refractive index profile. [2 marks]

(iii) With the help of suitable refractive index profile diagrams, compare the difference between the fibers in your answer for Question 1(b)(ii). [4 marks]

(iv) Based on your answer for Question 1(b)(ii), which type of fiber supports a higher number of guided modes? Justify your answer. [3 marks]

(v) A fiber with a parabolic refractive index profile has an NA in air of 0.21 and a core diameter of 50 μm. Estimate the number of guided modes in the fiber. [4 marks]

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Question 2 (25 marks)

(a) Describe THREE (3) loss mechanisms that are responsible for signal attenuation within optical fibers. [6 marks]

(b) Can dispersion affect the maximum data rate in digital transmission? Justify your answer. [3 marks]

(c) A 20 km optical fiber link is implemented using fiber with a loss of 0.5 dB/km.

(i) What is the signal attenuation in the optical fiber link assuming there are no connectors or splices? [1 mark]

(ii) Assume that the fiber is joined every kilometer with connectors which give an attenuation of 0.4 dB each. What is the overall total signal attenuation for the 20 km optical fiber link? Your answer should include losses due to the connectors. [3 marks]

(iii) Calculate the minimum mean optical power which must be launched into the fiber in order to maintain a mean optical power level of 0.5 μW at the detector. [3 marks]

(d) *Fiber 1* and *Fiber 2* have characteristics given in Table 1. Assume that these two fibers are perfectly aligned with no gap between them and that light is going from *Fiber 2* to *Fiber 1*. Calculate the total insertion loss at the splice. The total insertion loss must include the loss due to mismatch of fiber core diameters, mismatch of refractive index profile and mismatch of fiber numerical apertures. Your answer should be up to 3 decimal points. [9 marks]

Table 1: Fiber characteristics

Parameter	*Fiber 1*	*Fiber 2*
Core index n_1	1.49	1.51
Index difference Δ	0.01	0.02
Core radius a	50 μm	62.5 μm
Profile factor α	2.15	1.85

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Question 3 (25 marks)

As a network engineer, you have been assigned to design an optical link between two cities. The requirements are summarized in Table 3.1. You may consider the following fiber choices (Table 3.2) in your design.

Table 3.1 Requirements

Bit-rate	10 Gb/s
Length	200 km
Minimum receiver power	-55 dBm
Power margin level	5 dB

Table 3.2 Optical Fiber

	Single Mode Fiber	**Multimode Fiber**
Attenuation at 1300 nm (dB/ km)	0.8	0.9
Attenuation at 1550 nm (dB/km)	0.2	0.25
Intermodal Dispersion Coefficient (ps/m)	0	10

(a) Based on Table 3.2, choose a suitable fiber type for your design. Justify your answer. [3 marks]

(b) Propose a suitable wavelength to be used in your design. Justify your answer. [3 marks]

(c) Propose a suitable optical source to be used in your design. Justify your answer. Your answer should include the maximum power in dBm and wavelength for your proposed optical source. [4 marks]

(d) Propose a suitable amplifier type to be used in your design. Justify your answer. Your answer should include the type of amplifier and how many amplifiers in your design. [4 marks]

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Question 3 (Continued)

(e) Propose a suitable network topology type to be used in your design. Justify your answer. Your answer should include the node connection and how messages are transmitted from node to node. [4 marks]

(f) Calculate the total attenuation in your optical link based on your proposed design. You may make assumptions on the number of connectors to be used in your design and the losses induced by any splices or connectors. Your answer should include the power margin level shown in Table Q3.1. [4 marks]

(g) Taking into account the total losses in the network link as per your answer in Q3 (f), calculate the optical power budget for the network link. Comment on your answer. [3 marks]

Question 4 (25 marks)

You are required to upgrade the transmission capacity of your proposed fiber network link in Question 3.

(a) Propose a suitable multiplexing scheme for the network upgrade. Justify your answer. Your answer should describe the proposed multiplexing scheme in detail. [6 marks]

(b) Propose a suitable multiplexer for the network upgrade. Justify your answer. Your answer should describe the proposed multiplexer in detail. [6 marks]

(c) Propose a suitable demultiplexer for the network upgrade. Justify your answer. Your answer should describe the proposed multiplexer in detail. [6 marks]

(d) Describe TWO (2) types of digital modulation scheme that can be used in the proposed fiber network link. [4 marks]

(e) Which type of digital modulation scheme is suitable for a higher bit rate network link? Justify your answer. [3 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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